E-7 REINFORCED WATERWAYS

PURPOSE & APPLICATIONS

A reinforced waterway is a permanently lined channel constructed down a slope having an erosion-resistant lining of concrete, stone, or other permanent material. The earth above the structure must be permanently vegetated or otherwise protected. Its purpose is to provide for safe disposal of runoff without damage by erosion or flooding and where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides and they reduce gully erosion.

This standard applies to waterways or outlets having linings reinforced and non-reinforced cast in-place concrete; flagstone mortared in place, or similar permanent linings other than riprap. Other permanent linings that can be considered are gabion mats or other durable manufactured erosion reinforcement mats. But it does not apply to stream channels or streambanks.

This practice applies if the following or similar conditions exist:

- Concentrated runoff, wetness, prolonged base flow or seepage is such that a lining is needed to control erosion.
- Steep grades, greater than 8 %, which would cause high velocity and erosion.
- The location is such that use by people or animals preclude the use of vegetated waterways or outlets.
- Highly erosive soils or other soil conditions which preclude using vegetation.
- Climatic conditions precluding using vegetation (construction past the growing season).

CONSIDERATIONS

- Water temperatures may be altered due to the changes in shading of natural and man-made channels.
- Wildlife habitats in the riparian zone will deteriorate by the change of water temperature and quality as discharged from lined waterways.

SPECIFICATIONS

Design Criteria

Reinforcement of a waterway may be consist of asphalt, concrete, corrugated metal pipe, grouted riprap, or gabions. It should be noted here that paved and rigid flumes are susceptible to cracking unless placed on well compacted fill (95% of Standard Proctor as determined by ASTM D-698), and are securely tied in to prevent frost heaving and undercutting of the structure by water. An alternative would be to use a flexible geomembrane under the riprap so it can move and not crack.

- Reinforcement must be added to waterways that are steeper than 8 %. The maximum slope of the channel shall be 1.5:1 or 67 percent.
- Curtain walls may be provided at the beginning and the end of a reinforced waterway to retard seepage. The curtain wall shall be as wide as the channel, extend at least 18 inches into the soil below the channel and have a minimum thickness of 6 inches.
- Concrete flumes shall have expansion joints at a maximum spacing of 90 feet. Eighteen inch long dowels of #4 reinforcing steel placed on 5-inch centers shall be located at all required joints

Capacity: The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year frequency, 24-hour duration storm at a minimum.

Velocity: Maximum design velocity shall be as shown below. Except for short transition sections, flow in the range of 0.7 to 1.3 fps of the critical slope must be avoided unless the channel is straight. Extra precautions shall be taken where high velocities are in other than straight reaches. Waterways or outlets with high velocities shall discharge into an energy dissipator.

DEPTH OF FLOW	MAXIMUM VELOCITY
2.3 ft	10 fps
2.0 ft	10 fps
1.0 ft	15 fps
0.3 ft	30 fps
0.0 ft	30 fps

Cross section: The cross section shall be parabolic, or trapezoidal. Cross sections made of monolithic concrete may be rectangular.
Side slope: The steepest allowable side slopes, horizontal to vertical, are:

Rock riprap: 2 to 1
Non-reinforced Formed concrete: 1.5 ft up vertical embankment sides
Slip-form concrete: 1 to 1 for less than 3-ft high embankments
Screened concrete or mortared flagstone: 1 to 1 for embankments less than 2 feet
2 to 1 for embankments 2 feet or more high

Note: *Non-reinforced concrete or mortared flagstone linings shall be used only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.*
Lining thickness: The minimum lining thickness shall be:

- **Rock riprap**: Riprap channels shall have a minimum thickness of 2.25 times the maximum stone diameter but not less than 8 inches (plus thickness of filter or bedding).
- **Concrete**: 4 inches (In problem areas, minimum thickness shall be 5 inches reinforced with welded wire fabric)
- **Flagstone**: 4 inches, including mortar bed

Related structures: Side inlets, drop structures, and energy dissipators shall meet the hydraulic and structural requirements for the site.
Geotextile or Gravel Filters or bedding: Filters or bedding shall be used to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to the RIPRAP SLOPE STABILIZATION and GEOTEXTILES BMPs. Weep holes may be used with drains if needed.
Contraction joints: Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 feet. Provide for uniform support to the joint to prevent unequal settlement.
Rock riprap or flagstone: Stone used for riprap shall be dense, angular and hard enough to withstand exposure to air, water, freezing, and thawing. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking. Refer to the RIPRAP BMP for additional information.

Construction Specifications

The foundation area shall be cleared of trees, stumps, roots, sod, loose rock, or other objectionable material.
The cross section shall be excavated to the neat lines and grades as shown on the plans. All soft sections and unsuitable material shall be removed and replaced with suitable material. The subgrade shall be thoroughly compacted and shaped to a smooth, uniform surface. For concrete channels, the subgrade shall be moist at the time the concrete is placed.
No abrupt deviations from design grade or horizontal alignment shall be permitted.
Concrete lining shall be placed to the required thickness. Provisions shall be made to protect freshly placed concrete from temperature variation and drying to ensure proper curing.
Filter, bedding, and rock riprap shall be placed to line and grade and in the manner specified. Riprap shall be placed so that it does not reduce the designed cross-section more than 10 percent.
Construction operations shall be done to minimize erosion and water pollution. All disturbed areas shall be vegetated or protected with a cover against soil erosion.

Material Specifications

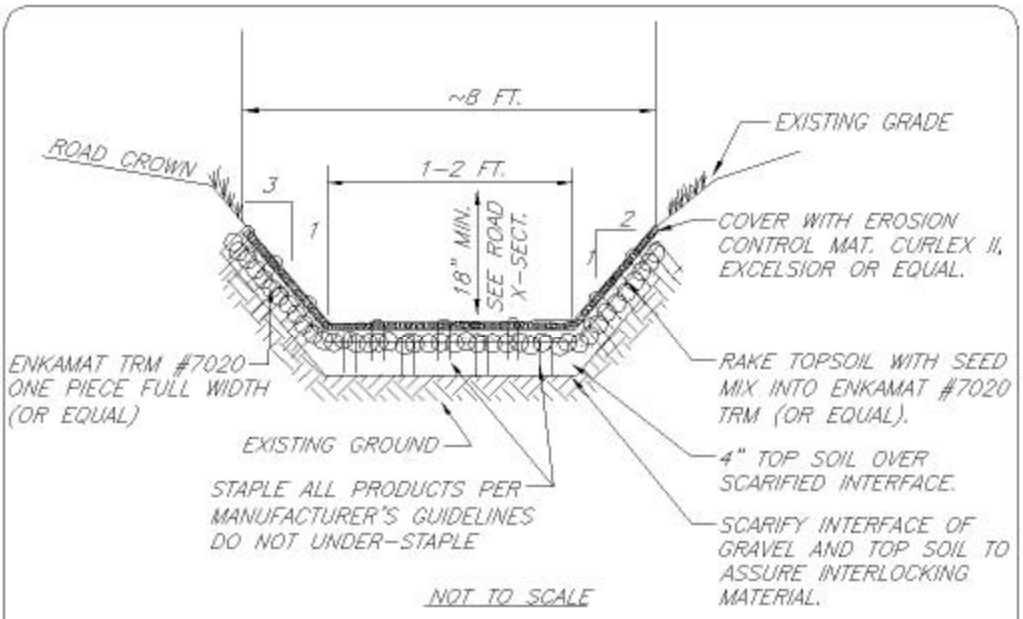
Concrete: Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense, durable product shall be required.
Mortar: Mortar used for mortared in-place flagstone shall consist of a workable mix of cement, sand, and water with a water-cement ratio of not more than 6 gallons of water per bag of cement.
Rock for Riprap: Rock shall be durable, and have the desired shape and size distribution to meet the design's needs.

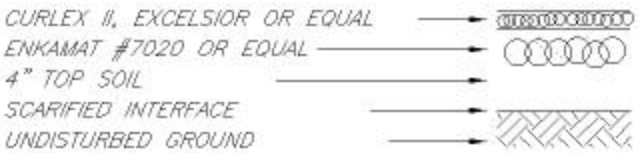
Schedule of Installation

Once soil is exposed for waterway construction, it should be immediately shaped, graded and stabilized. Lined waterways should be completely stabilized prior to directing runoff to them.

MAINTENANCE

Before permanent stabilization of the slope, the structure shall be inspected after each rainfall and damages to the slope or the paved flume repaired immediately. After the slope is stabilized, little maintenance should be required.





EXPANDED CROSS SECTION

REINFORCED VEGETATED DITCH
TURF REINFORCEMENT MAT (TRM)

TRMs SHOULD NOT BE USED:

1. TO PREVENT DEEP-SEATED SLOPE FAILURE DUE TO CAUSES OTHER THAN SURFICIAL EROSION.
2. WHEN ANTICIPATED HYDRAULIC CONDITIONS ARE BEYOND THE LIMITS OF TRMs AND NATURAL VEGETATION.
3. DIRECTLY BENEATH DROP OUTLETS TO DISSIPATE IMPACT FORCES (ALTHOUGH THEY MAY BE USED BEYOND THE IMPACT ZONE).
4. WHERE WAVE HEIGHT MAY EXCEED 12 INCHES (ALTHOUGH THEY MAY BE USED TO PROTECT AREAS UP-SLOPE OF THE WAVE IMPACT ZONE).
5. FOR COLD WEATHER SEEDING (DORMANT SEEDING) APPLY SEEDING AT TWICE THE SPECIFIED RATE. SPRING OVERSEEDING MAY BE DONE DIRECTLY OVER MATS.

REINFORCED VEGETATED DITCH (TRM)

FILE: TRMEVEGDITCH